Lecture 3

Know

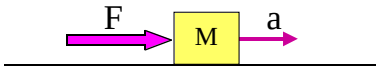
1. Newton's 3 laws of motion
2. How to apply Newton's laws in familiar situations
3. The basic units for mass and force
4. How to use vectors in calculating the effects of forces

Understand

1. The difference between the approach of Aristotle versus that of Galileo and Newton in describing the relationship between force and motion
2. The difference between mass and weight.
3. How to calculate the acceleration produced by a given force
4. The effects of friction and air resistance upon motion.
5. How to draw and use a free body diagram

Newton's Three Laws

- Any object remains at rest or in motion along a straight line with constant speed unless acted upon by a net force
- The product of the mass (m) of any object times its acceleration (a) is equal to the net force (F) acting on the object: **F**=m **a**



$$F = ma$$
$$a = F / m$$
$$m = F / a$$

- For every force, or action there is an equal but opposite force, or reaction.

Newton's work on gravitational force

- **There is a popular story that Newton was sitting under an apple tree, an apple fell on his head, and he suddenly thought of the Law of Gravitation.**

Weight

- **Weight** is a force generated by the gravitational attraction of the earth
- **Weight** is a force (measured in Newtons) and it is always directed toward the center of the earth. The magnitude of the force depends on the mass of the object:

$$W = mg$$ **(measured in Newton)**

where g is the gravitational acceleration on Earth surface

$$g = 9.8 m / s^2$$

Weight in Other Worlds

- Gravitational force is different in other worlds as it depends on the mass and size of the planet or star

Sun

$g_{Sun} = 265.3 m / s^2$

Mars

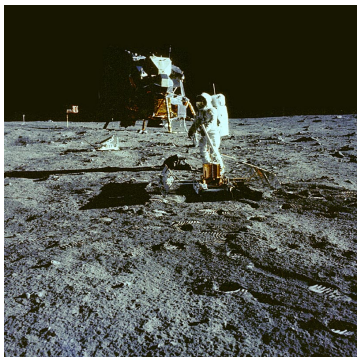
$g_{Mars} = 3.7 m / s^2$

Moon

$g_{Moon} = 1.6 m / s^2$

- If you put the same object on the Moon and weighed it, its weight would be 1/6 the weight on Earth

Weight on the Moon



- See Movie of astronauts walking on the moon ….
- 60 kg mass corresponds to
  - a weight of 130 lb on Earth
  - a weight of 22 lb on the Moon.

Mass vs Weight

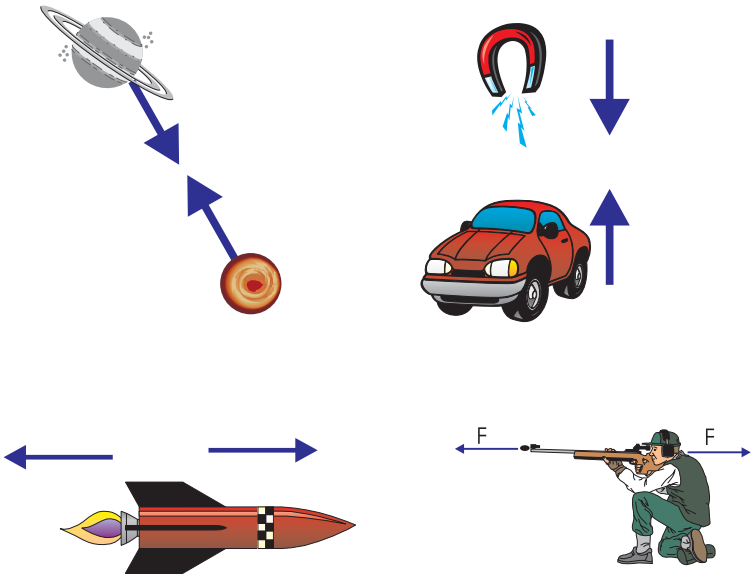
- Mass is the quantity of matter in an object.
- Weight is a force exerted on a mass in a gravitational field
- Mass is the same everywhere, but weight changes with local gravitational acceleration
- 100 kg mass on Earth = 100 kg mass on Moon

Newton's Third Law of Motion: Action/Reaction Principle

- For every force, or action there is an equal but opposite force, or reaction.
- This Law tells us that a force does not exist in isolation
- A force act between two objects either in contact or at a distance

Third Law of Motion in Action

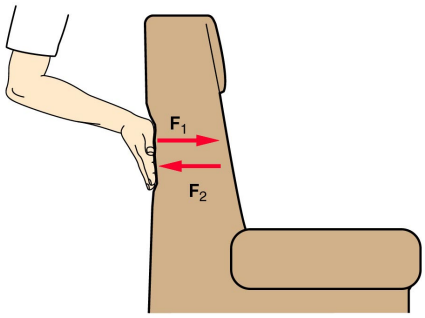
- We feel the third law every time we interact with other surroundings.
- For example when you punch someone in the face you know that your hand applies a force to the person's face, but the person's face also applies a force to your hand. Usually, the reason it hurts the face more than the hand is because the face is softer than the hand.



Example: Pushing a chair

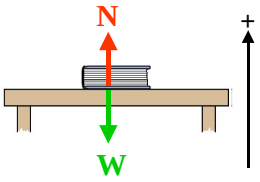
- You push the chair with a force F_1
- The chair acts on your hand with a force F_2 that is equal in magnitude to F_1 but in the opposite direction:

$$F_2 = -F_1$$



Normal Force

A book is at rest on the table:
What are forces on book?



- System is "in equilibrium":

acceleration = 0 fi net force = 0

1) The Force of gravity (W) pulling toward the Earth

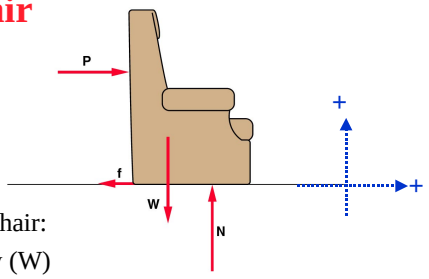
2) Gravity must be balanced by another force, the Normal Force (N) in the opposite direction

$$\hat{A}\, F = ma = 0$$
$$N - mg = ma = 0 \quad \Rightarrow \quad N = mg$$

Normal Force

- The force opposing gravity is caused by the table and it is known as the Normal force.
- "Normal" is not meant as "ordinary" but "perpendicular" or "orthogonal". The normal force is perpendicular to the surface that causes it.
- The normal force arises from the repulsive forces between the atoms at the surface of the book and the atoms at the surface of the table.

Pushing a Chair



Forces acting on the chair:

- Force of gravity (W)
- Normal Force (N)
- Force exerted by pushing hand (P)
- Frictional force (f)
- Equation for motion:

Horizontal → $\hat{A}F = P - f = ma_{horizontal}$

Vertical → $\hat{A}F = N - mg = ma_{vertical} = 0$

Drag or Air Resistance

- Drag or air resistance is the force which opposes an object moving through air
- Drag tends to increase as the object moves faster
- The amount of drag depends on the shape of the object